

SECTION 00565 - CARBON FIBER REINFORCED POLYMER STRENGTHENING - WET LAYUP SYSTEM

(Follow all instructions and make all edits with "Track Changes" turned on. This Section is not published in the Oregon Standard. If there are no instructions [purple text] above a subsection, paragraph, sentence, or bullet, then include it in the project, unless the item(s) that are included in the subsection, paragraph, sentence, or bullet are not required on the Project and then they should be deleted. In general do not re-number or re-letter subsections when item(s) are deleted. Delete all purple text before preparing the final document. All other modifications to this Section will require ODOT Technical Resource and State Specifications Engineer approval.)

Section 00565, ~~which~~ is not in the Standard Specifications ~~and~~, is included for this Project by Special Provision.

Description

00565.00 Scope - This Work consists of the complete installation of Carbon Fiber Reinforced Polymer (CFRP) sheet and laminate material, applied to existing concrete surfaces as shown and specified. This Work also includes the design of the CFRP strengthening by the CFRP system manufacturer's Engineer based on the loading requirements and design parameters as shown.

00565.01 Abbreviations and References:**(a) Abbreviations:**

CFRP - Carbon Fiber Reinforced Polymer

ICRI - International Concrete Repair Institute

(b) References:

AASHTO Guide Specifications for Design of Bonded CFRP Systems for Repair

ACI 440.2R, *Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures*

ACI 546R, "Guide to Concrete Repair"

ICRI Technical Guideline No. 310.1R, *Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion*

ASTM D3039, *Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*

ASTM D4541, *Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers*

ASTM D7522, *Standard Test Method for Pull-Off Strength for FRP Laminate Systems Bonded to Concrete Substrate*

00565.02 Submittals:

(a) Materials Certifications - At least 21 Calendar Days prior to starting CFRP system installation Work, provide manufacturer's material certifications for all CFRP materials, the strengthening system, and the surface coating material. Include the supplier's name and ranges of the properties listed below with test methods used for CFRP, epoxy, and system components.

Material	Properties to be Furnished
Primary Fibers	Tensile strength, Elongation, Tensile Modulus
Transverse Fibers	Tensile Strength, Elongation, Tensile Modulus, (Perpendicular to Surface Finishes Primary Fibers)
Epoxy Resin	Tensile Strength, Elongation, Tensile Modulus, Coefficient of Thermal Expansion , Mix Ratio, Pot Life, Shelf Life, UV Resistance
CFRP System	Tensile Properties, including method of reporting properties (net fiber or gross laminate), Test Methods used, and the statistical basis used for determining the properties

Submit the following information from the CFRP manufacturer:

- Installation instructions, inspection instructions, maintenance instructions, and general recommendations regarding each material to be used. Include surface preparation requirements in the installation procedures.
- Manufacturer's Safety Data Sheet (SDS) for all materials to be used
- Quality-control procedure for tracking CFRP materials and material certifications
- Durability test data for the CFRP system in the types of environments expected

(Use the following paragraph and bullets, except when a sand-mix surface finish is used.)

Submit the following information from the surface finish coating manufacturer:

- Manufacturer's product data sheets
- Manufacturer's material safety data sheet (MSDS)
- A manufacturer's letter containing any surface preparation or application recommendations ~~which may~~that differ from the published manufacturer data sheet including ~~but not limited to~~ additional recommended substrates for application or application to partially cured epoxy resin during CFRP installation

(b) Test Results - At least 21 Calendar Days before starting CFRP system installation Work, conduct longitudinal tensile property testing on 5 samples of a single CFRP ply for

each CFRP strengthening system according to ASTM D3039 and submit test results including tensile strength, elongation, modulus of elasticity, fabric material, epoxy, thickness, orientation of fibers, and curing method. Ensure CFRP system samples have the same physical properties as and are from the same manufacturer as the system to be installed in permanent Work.

(c) Personnel Qualifications - Submit personnel qualifications at the pre-construction conference according to 00565.30.

(d) Working Drawings and Calculations - Submit stamped Working Drawings, according to 00150.35(b), for each installation of composite material detailing all information required for the proper construction of the CFRP system at each location. ~~The Provide~~ drawings ~~must be~~ accompanied by ~~the~~ design calculations. Design the externally bonded CFRP system according to the requirements of ACI 440.2R or *AASHTO Guide Specifications for Design of Bonded CFRP Systems for Repair* given the design parameters as shown.

On the Stamped Working Drawings include, ~~but not be limited to~~, the following information:

- Properties and locations of CFRP materials
- Number, thickness and fiber orientation of layers. Except for a complete wrap system, limit a number of CFRP plies to 3 or fewer, unless otherwise shown.
- A separate drawing showing the locations where each CFRP layer is discontinued, if thickness of the CFRP laminate is changed.
- Details of joints and ends
- Anchorage system details to enhance bond and to develop required strength of CFRP laminate. Design anchorage system having tensile capacity at least 5 percent greater than the design tensile strength of the CFRP strengthening system, unless otherwise shown.

As-constructed plans of the existing structure(s) are available from the Engineer.

Do not begin CFRP work until the stamped Working Drawings and supporting calculations have been reviewed by the Engineer.

Materials

00565.10 General - Select a manufacturer and Materials from the QPL. Furnish all components to construct CFRP strengthening system from a single manufacturer. No substitutions are allowed, except as recommended by the manufacturer and as approved by the Engineer.

00565.11 Acceptance Testing - The following test is required for acceptance of the CFRP strengthening work:

(a) Bond Test - Conduct 5 bond tests to verify adhesion between CFRP laminate and the concrete surface. Prepare specimens at the Project Site, using the same CFRP materials, epoxy and number of CFRP plies used on each type of installation on the bridge. Ensure the test complies with the requirements of ASTM D4541, ASTM D7522 or other approved

method. Under the bond test, ensure the bond between CFRP laminate and concrete is stronger than the shear strength of the concrete (the laminate should peel off with concrete still attached to the bond surface).

Submit test results and inspection results including fiber orientation, delaminations, cure of resins and cured thickness to the Engineer for evaluation and acceptance.

(Use the following paragraph, except when a sand-mix surface finish is used.)

00565.12 Surface Finish Coating - Furnish a water based 100% acrylic or acrylic copolymer coating designated for exterior vertical and overhead applications, on concrete, masonry, stucco, and FRP as recommended by the CFRP manufacturer. Provide a color that matches existing concrete.

Labor

00565.30 Personnel Qualifications - Provide a CFRP Application Advisor, certified by the manufacturer of the CFRP materials to have been trained in installation of CFRP, to provide technical assistance prior to and during CFRP Work. Ensure the CFRP Application Advisor remains available for consultation until the completion and acceptance of all CFRP Work.

Provide trained personnel for installation of the CFRP system.

Provide the following information to verify the contractor's experience and the qualifications of personnel scheduled to perform the CFRP system:

(1) CFRP System Application Advisor Certification - Submit the CFRP manufacturer's certification of the Contractor's designated CFRP Application Advisor.

(2) CFRP System Application Advisor Certification Experience - Submit documentation showing that the Contractor's designated CFRP Application Advisor has experience as CFRP Application Supervisor, CFRP Application Advisor, or lead worker on 3 Bridge or building projects using CFRP wet-layup system in the last 5 years. The CFRP material used on projects submitted for experience does not need to be from the same manufacturer as material proposed for this Project.

For each project submitted, include:

- Project name
- Contract number
- Location
- Owner, including contact person's name and telephone number
- Date of contract acceptance (month and year)
- Material used and material manufacturer

(3) Applicators Certification - Submit certification from the CFRP material manufacturer, or from the Contractor's designated CFRP Application Advisor, affirming that the applicators installing the CFRP system have been trained in the installation of CFRP.

Construction

00565.40 Surface Preparation - Prepare surfaces for CFRP application according to the following:

(a) Surface Cleaning - Prepare concrete surfaces to be coated with CFRP according to the manufacturer's recommendations. Grinding, sandblasting, or a combination of both may be necessary. Comply with ACI 546R, *Concrete Repair Guide* and ICRI Technical Guideline No. 310.1R, *Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion*. Provide a minimum concrete surface profile (CSP) 3 according to ICRI. The Engineer will resolve any conflict between the manufacturer's recommendations and the named guides. Ensure the concrete surface is clean, structurally sound, dry and free of standing water. Remove dust, laitance, grease, curing compounds, impregnation, waxes, foreign particles, any disintegrated materials and any other bond-inhibiting matter using abrasive or water-blasting techniques.

Collect material removed during surface-preparation operations on plastic tarps or geotextile fabric, or by other approved methods. Dispose of all materials according to 00290.20.

(b) Crack Repair - Inject cracks that are 1/64 inch and greater in width according to Section 00538.

(c) Surface Repair - Use approved repair mortar recommended by the CFRP manufacturer to repair uneven surfaces and fill voids larger than ~~4/2-inch~~ 1/2-inch diameter or 1/8 inch deep. After the surface is repaired, ensure the residual unevenness is no more than the tolerances recommended by the CFRP manufacturer or 1/32 inch over 1 foot, whichever is smaller.

(d) Concrete Substrate Test - Verify the adhesive strength of the concrete after surface preparation at a random location by using a pull-off test according to 00565.11(b). A minimum tensile strength of 200 psi with concrete substrate failure is acceptable.

(e) Corners - Where CFRP sheet wraps around the corners of rectangular cross sections, round and smooth the corners to a minimum ~~4/2-inch~~ 1/2-inch radius.

(f) Priming Concrete Surface - Apply primer to the concrete surface according to the CFRP manufacturer's recommendations.

(g) Epoxy Resin Undercoating - If required by the CFRP manufacturer, apply epoxy resin undercoating according to the CFRP manufacturer's recommendations and the instructions of the resin manufacturer. The Engineer will resolve any conflict between the CFRP manufacturer's recommendations and the resin manufacturer's instructions. Do not apply epoxy resin, unless surface temperature and ambient temperature are between 50 °F and 90 °F.

00565.41 Curing CFRP Material - Cure CFRP material using the manufacturer's suggested methods and temperatures. Ensure that cured composites have uniform thickness and density, complete bonding between layers, and no porosity.

~~(Use one of the following subsection .42 Options paragraph, except when a sand-mix surface finish is used.)~~

00565.42 Application of Final Surface Finish —

[Option 1 - Use the following except when a sand-mix surface finish is used.]

Roughen the surface by lightly sanding with 100 to 150 grit sandpaper using hand or power tool methods or as recommended by the CFRP and coating manufacturers. Do not expose the fibers of the composite. Wipe the surface clean using clean cloths and water or solvent as recommended by the coating manufacturer. The coating may be applied to tacky epoxy surfaces ~~which that~~ do not transfer any material and are hard to the touch without surface preparation if approved by the coating manufacturer. Prepare All surfaces ~~which that~~ have reached full cure, are no longer tacky to the touch, or after 7 Days, whichever is less, ~~must be prepared~~ by hand or power tool methods approved by the Engineer.

Apply 2 surface finish coats, following all manufacturer recommendations. Prior to applying the finish coat, prepare a 3 feet by 3 feet sample for the Engineer's approval on an inconspicuous area of the Structure. Allow to dry. Obtain the Engineer's approval of the color before proceeding with the final surface finish.

Ensure all cured coatings are well adhered by probing edges or surface imperfections with a dull putty knife. Repair all cracked or delaminated coatings by removing the damaged coatings by hand or power tool methods and reapplying the coatings following all manufacturer recommendations. Feather edges 1 to 2 inches.

[End Option 1]

~~**[Option 2 - Use the following subsection .42 when a sand-mix surface finish is used.]**~~

~~**00565.42 Application of Final Surface Finish**~~—Apply No. 8 sand mix with the final coat of epoxy resin on all exposed surfaces, unless shown otherwise. Broadcast the sand mix to the final coat before epoxy resin solidifies.

After curing of the final coat, float the surface with a rubber or sponge, using a paste of fine mortar sand, cement, water, and bonding agent to fill air holes or voids to bring the surface to a uniform texture. Keep the retextured surface damp a minimum of 12 hours or until the paste has set, whichever is longer. If dustings occur after the retextured surface sets and is rubbed, refinish the surface. Provide a finish color of shade that matches existing concrete.

Prior to applying the finish coat, prepare a 3 feet by 3 feet sample for the Engineer's approval on an inconspicuous area of the structure. Allow to dry. Obtain the Engineer's approval of the color before proceeding with the final surface finish.

[End Option 2]

00565.43 Repair of Installed CFRP System Defects - Repair delamination areas of installed CFRP strengthening system with epoxy injection for defect size between 1/4 inches and 6 inches in diameter. Replace delamination areas for defect size greater than 6 inches in diameter.

Measurement

(Fill in the blank with the square feet.)

00565.80 Measurement - No measurement of quantities will be made for Work performed under this Section.

The estimated quantity for the proposed CFRP strengthening is _____ square feet despite the number of layers.

(Include the following paragraph when Sand-mix Surface Finish is specified. Fill in the blank.)

The estimated quantity for the sand-mix surface finish is _____ square feet.

Payment

00565.90 Payment - The accepted quantities of Work performed under this Section will be paid for at the Contract lump sum amount for the item "CFRP Strengthening - Wet Layup System."

Payment will be payment in full for furnishing and placing all Materials, and for furnishing providing all Equipment, tools, labor, and Incidentals necessary to complete the Work as specified.

No separate or additional payment will be made for:

- Furnishing and applying a surface coating.
- Training and certification of personnel.
- Repair of delamination areas due to installation defects.